Learning, innovation and proximity

An empirical exploration of patterns of learning: a case study

Leon A.G. Oerlemans

Eindhoven Centre for Innovation Studies

Faculty of Technology Management, Eindhoven University of Technology

P.O. Box 513, NL-5600 MB

Eindhoven, The Netherlands

Marius T.H. Meeus

Eindhoven Centre for Innovation Studies

Faculty of Technology Management, Eindhoven University of Technology

P.O. Box 513, NL-5600 MB

Eindhoven, The Netherlands

Frans W.M. Boekema

Faculty of Economics, Tilburg University

P.O. Box 90153, NL-5000 LE Tilburg

Faculty of Policy Sciences, University of Nijmegen

P.O. 9108, NL-6500 KH, Nijmegen, The Netherlands

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Abstract:

Literature on organisational learning and regional systems of innovation takes the embeddedness or relational perspective on innovation as a point of departure. Moreover, in studies on proximity the existence of embeddedness is often taken for granted. But, is embeddedness always as important for innovation as assumed? And, is proximity really of importance in (regional) systems of innovation. In this paper, these questions are explored empirically. After a brief discussion of theoretical literature on organisational learning, economics networks, and spatial proximity, the paper focuses on the empirical exploration of patterns of learning in a specific Dutch region. We try to answer the research questions mentioned below using survey data from roughly 700 industrial firms located in the Dutch region Noord-Brabant:

- If learning organisations are depicted as problem-solving actors, it is obvious to assume a relation between the number of innovation problems and the results of innovation. So, to what extent do innovation problems influence results of innovation?
- Learning has both an internal as an external dimension. To what extent do internal functions and external actors as elements of the system of innovation contribute to the results of innovation?
- Organisations learn by coping with (innovation) problems. We assume that different problem levels of the innovation process ate associated with different patterns of learning. This raises the following question: To what extent are the relations between internal and external contributions on the one hand, and the results of innovation on the other, influenced by different levels of innovation problems?
- Innovating organisations learn through their external relations. Proximity is thought to be of importance in these learning processes. Is proximity indeed of importance in these relations?

Our findings revealed that the obvious negative relation between the number of innovation problems and the results of innovation was not confirmed. Learning organisations were able to cope with these problems in such a way that their innovation outcomes were not hampered. Furthermore, the embeddedness perspective on innovation was confirmed empirically. But, the estimations proved to be sensitive to the amount of innovation problems encountered by firms. The more problems firms encounter, the more important external resource bases are for the innovation process. Our findings concerning the importance of proximity were somewhat puzzling. On the one hand, it turned out that proximity is indeed of importance for innovation processes. On the other hand, our findings revealed that the assumptions of Lundvall and Maillat regarding the relations between the character of technological change and spatial interactions were not confirmed. From these findings one can conclude that proximity is indeed of importance for the innovating firms in this research, but other variables than the ones proposed by Lundvall and Maillat influence the spatial distribution of innovative network relations in the system of innovation.

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INTRODUCTION

A growing body of theoretical research is addressing the importance of learning in the organisational and technological renewal of firms, and therefore in their efforts to improve competitiveness (Daft & Huber, 1987; Levitt & March, 1988; Huber, 1991; Dodgson, 1993; Blackler, 1995; Dodgson, 1996). In these discussions, regions are thought to have important features for facilitating innovation too (Florida, 1995, Cooke, Gomez Uranga, Etxebarria, 1997; Morgan, 1997). This paper reviews literature on organisational learning and networks, learning regions as systems of innovation, and the role of proximity in the transfer of information and knowledge.

Literature on organisational learning and regional systems of innovation takes the embeddedness or relational perspective on innovation as a point of departure. Moreover, in studies on proximity the existence of embeddedness is often taken for granted. But, is embeddedness always as important for innovation as assumed? And is proximity really of importance in systems of innovations? In this paper, these questions are explored empirically. After a brief discussion of theoretical literature on organisational learning, economic networks, and spatial proximity, the paper focuses on the empirical exploration of patterns of learning in a specific Dutch region. Learning organisations are depicted as problem-solving actors. In coping with innovation problems, actors participate in different kinds of networks. Finally, the spatial dimension of these networks is investigated.

ORGANISATIONAL LEARNING AND ECONOMIC NETWORKS

Conceptions of organisational learning are omnipresent. Not only organisational theory has addressed the issue, but a range of other academic disciplines (e.g. industrial economics, strategic management, and psychology) have also studied it. A number of reasons can be suggested why the study of organisational learning is so fashionable at present (Dodgson, 1993). First, learning is seen as a key to competitiveness. Learning enables organisations to develop structures and systems that are more adaptable and responsive to change. Second, and partly related, is the deep influence that rapid technological change has on organisations. There is an increasing need for firms to learn to do things in a new, and often drastically different, way. Third, the concept of learning has a broad analytical value.

Both within and between disciplines there is rarely any agreement as to what learning is, and how it occurs. Various fields of literature tend to examine the outcomes of learning, rather than inquire as to what learning actually is and how these outcomes are achieved. Learning, in the sense it is used here, relates to firms, and comprises both processes and outcomes. In general terms (Huber: 1991), someone/something learns if the range of its potential behaviours is changed through the processing of information. More specifically for organisations, it can be described (Dodgson, 1996) as the ways firms build, supplement, and organise knowledge and routines around their competences and within their cultures, and adapt and develop organisational efficiency by improving the use of these competences. Competences are the focussed combination of resources within a firm, which define its business activities and comparative advantage. This definition of organisational learning contains a number of important assumptions (Dodgson, 1993):

- Learning has positive consequences even though the outcomes of learning may be negative. Here, it is important to note that firms learn by making mistakes and solving problems. Morgan (1997) also stresses the problem-solving capacity of learning organisations.
- Although learning is based on individuals in the workforce of the firm, it is assumed that firms can learn.
- Learning occurs throughout all the activities of the firm. It occurs at different speeds and levels. Encouraging and co-ordinating the variety of interactions in learning is a key organisational task.

How do firms learn? A major mechanism by which firms learn about technology is through their internal R&D efforts. They also learn, of course, from a wide range of other internal functions, particularly from marketing and manufacturing and from the interactive interactions between these functions. Furthermore, learning has both an ‘internal’ and ‘external’ component. External links, with customers, suppliers, and other sources of information and knowledge, are critical in assisting a firm’s learning processes.

The argument that external links are important for firms as proposed by literature on organisational learning, can also be found in literature on economic networks. The main difference between these two bodies of literature is that in the former the accent is on the importance of these links for the *learning processes* of firms, whereas in the latter the emphasis is on the formation of network structures and their *impact on the innovation process*. The network structures enable innovating firms to perform in a more efficient way.

The economics network approach, especially as developed by Håkansson (1987, 1989, 1992, and 1993) and Håkansson & Snehota (1995), provides us with a framework to analyse the relation between learning, innovation and networks. Håkansson’s economic network model contains three main elements: actors, activities, and resources. *Actors* perform activities and possess or control resources. They have a certain, but limited, knowledge of the resources they use and the activities they perform.

Their main goal is to increase their control of the network. Actors in networks can be studied at different levels, from individuals to groups of firms. Two main types of *activities* are distinguished in the network model: transformation and transaction activities. Both are related to resources because they change (transform) or exchange (transact) resources through the use of other resources. Transformation activities are performed by one actor and are characterised by the fact that a resource is improved by combining it with other resources. Transaction activities link the transformation activities of the different actors. These exchanges result in the development of economic (network) relations between actors. There are several types of *resources*: physical (machines, raw materials, and components), financial and human (labour, knowledge, and relations). Furthermore, resources can be classified according to the degree of organisational control. In the case of internal resources the firm has hierarchical control. External resource providers control external resources. As a consequence, resources are heterogeneous, i.e. their (economic) value depends on the other resources with which they are combined.

Despite Håkansson's claim that resources or knowledge bases are heterogeneous, and internal and external, he does not specify which bases he is referring to. If we assume that innovation is a knowledge-intensive process, we must determine which 'knowledge bases' (Dosi, 1988: 126) innovators can use. Smith (1995: 78-81) systematises the attributes of, what he calls, a 'modern view' on technological knowledge. One of these attributes is that technological knowledge is differentiated and multi-layered. At least three different knowledge bases can be discerned. First, there is the general (scientific) knowledge base. This base is highly differentiated internally and of varying relevance for industrial production and innovation. Secondly, knowledge bases exist at the level of the industry or product field and entail shared understandings of technical functions, performance characteristics, use of materials, etc., for products and processes. This knowledge and these practices shape the performance of firms in an industry. Thirdly, the knowledge bases of firms are highly localised and specific. They tend to comprise one or a more technologies and practices that they understand well and form the basis of their competitive position. This firm-specific knowledge base is not only technical, but also concerns the way in which technical processes are interwoven with other firm activities. These include identifying market opportunities, financing, purchasing, and marketing new products and processes.

The fact that knowledge bases of (industrial) firms are multi-layered has two important consequences for the use of Håkansson's economic network model. Firstly, it means that although individual innovating firms are competent in specific areas, their competence is nonetheless limited. In other words, innovating firms use their specific knowledge bases to innovate but they can easily run into problems. The solution of these problems may lie outside their area of expertise. Therefore, they must be able to access and use new internally and/or externally generated knowledge (learning) to solve these problems. Secondly, the multi-layered and heterogeneous nature of knowledge bases makes it necessary to distinguish several actors and institutions inside and outside the firm in which knowledge is embodied. Internal resources are embodied in the transformation (R&D, production) and transaction (purchase, marketing/sales) functions of the firm. Outside the firm, at least three groups of actors can be distinguished: the public and private knowledge infrastructure, and the production chain. The public knowledge infrastructure consists of organisations such as universities and colleges for professional and vocational training. These knowledge bases are mainly of a general (scientific) kind. Trade organisations, consultants, and intermediaries such as Chambers of Commerce and regional Innovation Centres populate the private knowledge infrastructure. The first two have technological knowledge mainly related to the industry or product field. The last two can be seen as information brokers. They are able to give general and specific information on innovation and business related issues, but they are also able to bring parties into contact with each other. The third and last group is called the production chain. Suppliers, buyers, and other firms such as competitors are part of this group. The technological knowledge embodied in these actors is also mainly related to the industry and product field.

The linking of learning, innovation, and networks hinges on the heterogeneity of resources and resource mobilisation. According to Håkansson (1993), the effects of heterogeneity are that knowledge and learning become important. How should the firm handle these heterogeneous resources? In answer to this question, Håkansson cites Alchian & Demsetz (1972: 793) who state that ‘efficient production using heterogeneous resources is not a result of having better resources, but knowing more accurately the relative performance of the resources’. In other words, it is not only necessary to have resources, but also to know how to use them.

This knowledge can be acquired in two ways: internally and/or externally. Learning to use internal resources can be accomplished in several different ways, for example through R&D activities or learning by using or doing. The external mobilisation of resources can be labelled ‘learning by interacting’ (Lundvall, 1988: 362), i.e., firms can use the knowledge and experience of other economic actors.

To make use of external resources, firms need to exist within structures that make these learning processes possible and efficient. According to Håkansson, economic network relations produce structures characterised by stability and variety. First, scarce external resources are more easily mobilised through stable relations with other economic actors. Second, stable relations in networks enable innovating firms to gather knowledge and to learn how to use heterogeneous resources innovatively and efficiently from other actors. Third, the stability of economic network structures provides a basis for variety. This variety offers new opportunities for innovation.[1]

The economic network approach makes it clear that firms can supplement their innovation process by using external resources. They can acquire knowledge supporting their innovation processes, through the use of their economic network relations.

Although the relational view on learning and innovation processes is important in the organisational learning literature and in the economic network approach, the spatial dimension is often left implicit. So, in order to focus on the link between learning, innovation, and proximity, these literatures have to be connected. This link can be found in the work of Lundvall on systems of innovation and in the work of Maillat on 'milieux innovateurs'.

SYSTEMS OF INNOVATION, 'MILIEUX INNOVATEURS' AND PROXIMITY

To make this link clear, one must go into the concept of RIS. A RIS can be divided into three parts that make up the term: Regional, Innovation and System. Before discussing the regional or spatial dimension, we shall first explore the concept of the innovation system.

Innovation can be defined as the process by which firms master and put into practice product designs and manufacturing processes that are new to them (Nelson & Rosenberg, 1993). Defined in this way, it is clear that innovation is a process. In this process new knowledge or new combinations of old knowledge are embodied in products and production processes and possibly introduced into the economy. Put in a simple way, *innovation is the result of learning processes*. Learning leads to new knowledge and firms use this knowledge in an attempt to improve products and production processes. As Lundvall (1992) stated, there now is growing support for the view that innovation is an interactive or a relational process: between firms and the knowledge infrastructure, between the different functions within the firm, or between users and producers. The interactive characteristics of the innovation process are the link with organisational learning.

In system theory, a system consists of a number of discrete elements and the relationships between them. A system of innovation therefore comprises elements of importance to innovation and the relationships amongst them. Florida (1995) describes the basic elements of a system of innovation: (1) a manufacturing infrastructure, (2) a human infrastructure, (3) a physical and communications infrastructure, (4) a capital allocation system and financial market. These infrastructures can facilitate the innovation processes of firms.

The relationships between the elements in a system of innovation are the linkages that can be specified in terms of flows of knowledge and information, flows of investment funding, flows of authority and other arrangements such as networks, clubs, and partnerships. As Cooke, Uranga & Etxebarria (1997) state, these linkages or interactions are clearly a social process in which institutions are of importance. Consequently, innovation is shaped by a variety of institutional routines and social conventions (Morgan, 1997).

What is the regional or spatial dimension of these systems of innovation? In theoretical literatures several answers to this question are proposed. One of these answers refers to the relation between proximity and the type of knowledge exchanged (Storper & Harrison, 1992; Cooke et al., 1997). Knowledge is thought to be partly codified and primarily tacit. The argument is that tacit knowledge is highly personal and specific, hence it is not easily codified and communicated. Learning organisations interact with their environment. This has become essential as more and more firms externalise business functions. Where externalisation involves interactions at great distances, codified knowledge can be exchanged reasonably satisfactorily. But innovation is intimately bound up with tacit knowledge exchange. This is difficult to achieve at a distance. It is of importance to understand why regional systems of innovation are a valuable feature of innovation-based competitive advantage.

A similar line of thought is developed by Lundvall (1992), who studies the relationship between the character of technological change and the spatial interactions. Three types of technological change are discerned, namely stationary technology, incremental innovation, and radical innovation that are each associated with specific patterns of spatial interaction between users and producers.

In the case of stationary technology, the technical opportunities as well as the needs of users are fairly constant. There are available norms, standards, and terminologies available giving a near complete description of the technology involved. In other words, knowledge is highly codified. Such a high degree of codification means that communication between users and producers can be performed over long distances. If this is the case, industries virtually become footloose.

For incremental innovation, codes and channels of communication must be flexible in order to include technological opportunities and changing user needs. Recurrent changes in product specifications, functions, and qualities of artefacts constrain standardisation. Consequently, codification of knowledge is more difficult. This means that messages are relatively complex and information cannot easily be translated. In this case space will play a role. The proximity of advanced users plays an important role in the adaptation process of an artefact to local conditions. Such industries, often a part of national industrial complexes, or clusters, are not footloose. Comparative advantages are often based on spatial proximity.

In the case of radical innovation, codes developed to communicate a constant, or a gradually changing, technology become inadequate. Producers who follow a given technological trajectory will have difficulties in evaluating the potentials of the new paradigm. Users will have difficulties in decoding the communications coming from producers, developing new products built according to the new paradigm. The lack of standard criteria for sorting out what is the best paradigm implies that 'subjective' elements in the user-producer relationships – like mutual trust and even personal friendship

– will become important. These subjective elements are not easily shared across regional borders. So, here spatial proximity is extremely important for user-producer interaction.

In sum, the more radical the process of technological innovation, the less codified knowledge is. The more tacit the knowledge communicated the more important spatial proximity between user and producer is. So, there is a positive relationship between the level of tacitness of knowledge and the importance of spatial proximity.

A comparable line of thought on the relationship between innovation and proximity is developed in the 'milieux innovateurs' approach. The work of Maillat (1991) is of particular interest. Maillat argues that there are links between some features of the innovation process and the local environment. The importance of the local environment for the innovation process depends on the type of innovation involved. In addition, the innovation strategies applied by firms influence the character of the relation with the environment.

Regarding the type of innovation, the local environment is of little importance for firms developing incremental innovations. The resources needed for this kind of innovation is easily found within the firm. Firms with radical innovations develop more relations with the local environment. Mostly, the external resources are also needed to realise this type of innovation.

Maillat also postulates relations between the type of innovation strategy and the local environment. He distinguishes two kind of strategies: the exploitation of an already existing technological trajectory and 'technology creation'. In the first case, innovation is a process in which an already existing technology is used. For firms using this innovation strategy, the local environment is 'an external datum whence the firm derived its inputs' (Maillat, 1991: 111). In the second case, the local environment is an essential part of the innovation process of the firm. Because the outcomes of this kind of innovations are uncertain or even unknown, Maillat argues (1991, 111): 'indeed, the creation of technologies presupposes that the environment becomes an essential component of innovation, that these various resources be used and combined to generate a new form of localised production organisation. The enterprise is then no longer isolated in a territory which represents to it only an external component, it helps to create its environment by setting up a network of partnership-style relations, both with other firms [....] and with public and private training and research centres, technology transfer centres and local authorities'.

If we compare the lines of reasoning of Lundvall and Maillat some differences and similarities come to the fore. The main difference between Lundvall and Maillat concerns the assumed links between the characteristics of the innovation process and proximity. Lundvall stresses the interaction component in the system of innovation, i.e., the relation between the nature of the knowledge exchanged and proximity. Moreover, Lundvall focuses on a specific kind of relation, namely between users and producers. Maillat, on the other hand, takes a more resource-based view on the relation between innovation and space. Depending on the type of innovation or strategy involved, other or more (external) resources are needed. The local environment is mainly viewed as a resource base, but relations can develop between a wide variety of (local) actors. Both assume a similar relation between innovation and proximity. In short, they assume that the more radical innovations are, the more important proximity is. Although Lundvall and Maillat differ in their opinion about the relation between incremental innovation and space, they agree on the relation between radical innovation and proximity. In our empirical section about the relation between innovation and proximity, we return to these issues.

RESEARCH QUESTIONS

The main aim of this paper is an empirical exploration of patterns of learning in a specific Dutch region. Answers are sought for the research questions mentioned below:

1. If learning organisations are depicted as problem-solving actors, it obvious to assume a relation between the number of innovation problems and the results of innovations. So, to what extent do innovation problems influence innovation results?
2. Learning has both an internal and external component. To what extent do internal and external knowledge bases as elements of the system of innovation contribute to the results of innovations?
3. Organisations learn by coping with (innovation) problems. We assume that different problem levels of the innovation process are associated with different patterns of learning. This raises the following question: To what extent are the relations between internal and external contributions on the one hand, and the results of innovation on the other, influenced by different levels of innovation problems?
4. Innovating organisations learn through their external relations. Proximity is thought to be of importance in these learning processes. Is proximity indeed of importance in these innovative relations?

METHOD

This paper is drawing on a survey on R&D, networks and innovation in the Dutch region Noord-Brabant. The survey was held in 1992/1993 (relating to behaviour in the period 19987-1992) among some 3,500 firms from manufacturing and services with more then five employees. The response rate was 19.6% (689 firms) and was quite even across sectors, although small firms responded somewhat less than larger ones (for details see Oerlemans, 1996: 188-191).

INNOVATION PROBLEMS AND INNOVATION RESULTS

For our first research question, we use a model where 'results of innovation' is the dependent variable, and manifest and latent knowledge deficiencies are the two independent variables each containing two measurements.

The dependent variable 'results of innovation' contains a count of the number of performance improvements due to product and process innovations (see Table 2) achieved by a firm during the period 1987-1992.[3] This variable is calculated as the sum of the scores of the items divided by 8. A higher score indicates better innovative performance.

Insert Table 2

Four independent variables were used. Two of them indicate latent knowledge deficiencies: LKD1 and LKD2. LKD1 measures the number of innovation problems distinguished by their causes (e.g. exceeding time schedules, bad timing, or insufficient marketing efforts). The variable LKD2 indicates the number of stages in the innovation process that were problematic (e.g. economic or technical feasibility). Higher values of these variables signify more innovation problems or more problematic stages in the innovation process, respectively. These variables are labelled *latent* knowledge deficiencies because we assume that real or manifest knowledge deficiencies are hidden behind the innovation problems mentioned by firms. After all, problems would not occur if the knowledge bases of the firms were sufficient in quantitative and qualitative terms.

The two other independent variables are labelled manifest knowledge deficiencies. On the one hand it concerns shortages of skilled workers, and the lack of technical knowledge on the other. Both variables are coded as dummies. The value 1 is assigned if these knowledge deficiencies constrain innovative activity. If this is not the case, the value of the variables is 0.

Using multiple regression analysis, the relationship between the dependent and the independent variables is investigated. The result of this analysis is presented in Table 3.

Insert Table 3

The results of the estimation only signify a partial confirmation of our expectations. Only the variables 'shortages of skilled workers' and 'lack of technical knowledge' show the expected negative relationship with innovation results. In other words, only variables indicating manifest knowledge deficiencies have an impact on innovative performance.

The percentage of variance explained of the estimation is extremely low (3%). Moreover, the magnitude of the beta coefficients is small and their statistical significance is poor. So, it can be concluded that the obvious assumption regarding the negative relationship between innovation problems and innovative performance is not empirically obvious at all.

Our analysis shows that latent knowledge deficiencies – the problems innovating firms encountered in the period 1987-1992 – did not constrain their innovation results. Our interpretation of these results is that innovating firms, however difficult it may be, are able to produce positive innovation outcomes. As learning organisations, they are capable of solving their problems. In the light of this interpretation the question emerges how these firms solve their problems and where they obtain the necessary resources.

COPING WITH KNOWLEDGE DEFICIENCIES: THE USE OF INTERNAL AND EXTERNAL KNOWLEDGE BASES

Our second and third research question concern the relationships between the use of internal and external knowledge bases as elements of the system of innovation, and their impact on the innovative performance of firms.

Again the variable ‘innovation results’ is used as the dependent variable. Furthermore, six independent variables are included in our analyses (see Table 4). Two of them describe the use of internal knowledge bases (transformation ‘(TF) and transaction (TA) function of the firm). Three external knowledge bases are discerned: public (EC1), private (EC2), and business (EC3) knowledge bases. These five variables are measured in the same way. Firms were asked how often in the past 5 years external organisations thought up ideas for, or made an important contribution to the realisation of innovations.[5] Higher values of these variables indicate a more intensive use of the knowledge base involved. The sixth independent variable is ‘technology policy’. It describes the total number of technology policy instruments used by a firm and can be interpreted as an external financial resource stimulating innovation provided by a government, and being part of the national system of innovation. The higher the score on this variable, the more technology policy instruments are used.

Insert Table 4

The number of innovation problems (LKD1) is used as a moderating variable.[5] With a rank procedure, innovating firms are divided into three subgroups: firms with low, medium, and high levels of innovation problems. In this way, it is possible to make separate estimations for subgroups.

In Table 4, different groups of actors who influence the innovation process were distinguished on theoretical grounds. Subsequently, the question was adressed whether these theoretical dimensions also exist empirically. In order to answer this question, factor analysis was applied which resulted in the three factors presented in Table 5.[6]

Insert Table 5

Factors EC1-EC3 represent contributions to the innovation process by the public and private knowledge infrastructure, and the production chain. In short, we can conclude that the results of this factor analysis empirically confirm the initial categorisation. Factors EC1-EC3 were used as independent variables in further regression analyses.

To investigate research question 2 and 3, four OLS models were estimated, one for the total response and three for the different levels of innovation problems. Once more, estimations are produced using multivariate regression analysis with the model in figure 2 as the point of departure. As can be seen in Table 6, all models are significant as indicated by the F-values and their levels of significance. The percentages of variance explained varies between 11% for the model with firms having medium problem levels in their innovation process, and 27% for the model with firms having a highly problematic innovation process.

The model that includes all responding firms shows that both the use of internal and external knowledge bases are positively related to results of innovation. The higher the contributions of the transformation function (internal knowledge base), the contributions of the private knowledge infrastructure and the production chain (external knowledge bases), the more positive the results of innovation. Therefore, the analysis shows that an additive combination of the use of internal and external knowledge bases results in a better innovative performance, stressing the importance of including network variables in the analysis of innovation.

Furthermore, it becomes clear that the estimations made for subgroups of firms distinguished by the number of innovation problems encountered differ strongly regarding the use of internal and external knowledge bases. Firms with a few innovation problems only use their internal transformation function to achieve better results. The second group, firms with medium problem levels, utilises the knowledge bases embodied in the transaction function to obtain a better innovative performance. The same is true for firms with high problem levels, the third group distinguished, though in this group the contributions of the private knowledge infrastructure, the production chain and the use of technology policy instruments are also positively related to innovative performance.

An interesting pattern emerges from these analyses. The more problems firms encounter in their innovation processes, the more these innovation firms take an external orientation. In other words, the system of innovation is especially of interest for firms with highly problematic innovation processes.

Next, it is interesting to examine which *specific* internal and external knowledge bases are positively related to the results of innovation. In order to perform this analysis, we used the individual items of the statistically significant independent variables and correlated them with results of innovation.

As a measure of association we used the Spearman rank correlation. The coefficients and their significance are presented in table 7.

Insert Table 7

For innovating firms with a low level of innovation problems, we see that especially the contributions of the production function are positively correlated with the results of innovation. The R&D function is also of importance, but to a much lesser extent. The transaction function made positive contributions to the results of innovation for firms with medium problem levels. Within this function, the contributions of the purchasing function to the innovation process proved to be positively related with results of innovation. The marketing function also has a positive tendency, but is not significant statistically. For firms with highly problematic innovation processes, the utilisation of internal knowledge bases is not enough to solve their problems. They have to obtain external resources too. Consultants, buyers, other firms, but especially suppliers become involved in the innovation process of these firms.

Our empirical findings enable us to formulate two conclusions. First, our analyses make clear that the number of problems that firms encounter in their innovation process is a factor of importance. The patterns of relations and learning in the system of innovation are strongly influenced by the different problem levels. Second, Von Hippel’s claim about the importance of buyers, the so-called lead-users, for the innovation process is differentiated. Important buyers are indeed making positive contributions, but it turns out that suppliers are even more influential.

Until now we have focussed on patterns of relations and learning without paying attention to the spatial dimension of the system of innovation. In the next section, this issue is dealt with.

SPATIAL PROXIMITY IN THE SYSTEM OF INNOVATION

As was stated in the previous section, innovating firms learn through their external relations. Spatial proximity is thought to be of importance in these learning processes. Is proximity indeed of importance in these relations? To answer this fourth research question, three approaches are used. First, we investigate the spatial distribution of buyers and suppliers who influence the innovation process. In this way, we have an indication of the importance of localised ties within the (regional) system of innovation. Second, we look at a specific characteristic of these relations: the transfer of knowledge. As was argued by Lundvall, precisely this feature of interaction between actors in the system of innovation is thought to have an important effect on the spatial distribution of innovative relations. Third, we investigate the relation between radicalness of innovations and spatial proximity. This analysis is based on the arguments of Lundvall and Maillat regarding the relation between the type of innovation and proximity.

The variables used to answer research question 4 are presented in Table 8. First, an important remark has to be made. In this section, the analysis is focussed on a specific group of relations of innovating firms. This pertains to the relations with other economic actors that are, in the view of the innovating firm, most important to the innovation process. Six variables are used in the analysis.

Insert Table 8

In the previous section, it was shown that especially suppliers and buyers are important external knowledge bases for innovating firms. To study the role of these economic partners more in depth, we asked the innovating firm several questions regarding the specific type of actors involved and various features of their network relations. First, we asked what kind of supplier (TS) or buyer (TB) was most important for the innovation process. Four types of suppliers (TS) were distinguished: suppliers of raw materials, product parts and components, machines and tools, and consultants. As regards the most essential buyers for the innovation process, three types were discerned: consumers, retail/wholesale, and industrial users. Second, we asked the innovating firm to indicate the spatial location of the buyer or supplier involved. Three possibilities to answer were provided: the southern part of the Netherlands, elsewhere in the Netherlands, and outside the Netherlands.[7] Third, the transfer of knowledge between the innovator and economic actors in the system of innovation is believed to have an important influence on the spatial embeddedness of relations in the system of innovation. Therefore, we asked the innovation firm to what extent knowledge transfers occured between supplier and buyer on the one hand, and the innovating firm on the other. Fourth, the spatial distribution of buyers and suppliers is supposed to be influenced by the type and level of innovation produced by the innovating firm. Therefore, we asked questions about the type of innovations (product or process innovations) and the level of the innovations (incremental or radical) produced by the firms.

Let us first look at the spatial distribution of suppliers and buyers essential to the innovation process (Table 9).

Insert Table 9

It is clear that suppliers of machines and tools are mentioned most often as the most important supplier contributing to the innovation process. Approximately 46% (125/273) of the innovating firms named this type of supplier. Suppliers of product parts and components come second (about 29%).

Industrial users dominate the group of buyers influencing the innovation process. About 58% of the innovating firms considers this type of buyer the most important for their innovation processes.

With regard to the spatial distribution of the suppliers, it appears that they are more or less equally distributed over the three geographical areas distinguished. This means that one out of three suppliers is located in the southern part of the Netherlands. The relations with suppliers of product parts and components and consultants in particular show signs of spatial concentration. About 53% of the consultants and 43% of the suppliers of components and parts are located in the southern part of the Netherlands. However, for the largest group of important suppliers (machines and tools) proximity seems to be less important.

As can be seen in the lower part of Table 9, buyers important for the innovation process are more spatially concentrated than suppliers are. Approximately 40% of these buyers are located in the proximity of the innovating firm. This percentage is even higher for industrial users. Nearly 50% of this type of buyers is located in the southern part of the country.

It can be concluded from this analysis that the spatial dimension of innovative relations is indeed of importance. A large part of the innovative relations with suppliers and buyers can be found in the proximity of the innovating firm. Our findings stress the importance of particular elements in the (regional) system of innovation for technologically active firms.

As was argued by Lundvall, the transfer of knowledge between actors in a system of innovation is supposed to be sensitive to geographical distance. Thus, the obvious choice is to investigate the relation between knowledge intensity of innovative relations on the one hand, and the spatial distribution of innovative relations on the other. The results of this analysis are presented in Table 10.

Insert Table 10

First, a comparison between relations with buyers and relations with suppliers regarding the extent of knowledge transfer shows that relations with suppliers are more knowledge intensive. 42% of the firms that have innovative relations with suppliers state that deliveries of suppliers are ‘often or always’ associated with the transfer of knowledge. The percentage for the innovative relations with buyers is about 25%.

Second, innovative relations with buyers and suppliers located in the southern part of the Netherlands are neither more nor less knowledge intensive than the relations with buyers and suppliers located in the two other geographical areas distinguished in our analysis. So, there seems to be no relation between the extent of knowledge transfer and the proximity of buyers and suppliers important for innovation.

Perhaps, this result has to do with fact that we did not make a specification, as Lundvall and Maillat propose, of the character of the technological change involved. After all, a consequence of their line of reasoning is that the importance of proximity for innovation depends on the technological opportunities and the needs of users. Using Lundvall’s ideas empirically, it is possible to formulate two expectations concerning the relation between the type and level of innovations and proximity:

1. In the case of firms with incremental process and product innovations, a large amount of the innovative relations with suppliers and buyers should be found in the southern part of the Netherlands. Because of restrictions in the standardisation process and the importance of tacit knowledge, proximity plays an important role in the process of the adaptation to local conditions of a product or process. If we apply the arguments of Maillat, the opposite should be the case. Due to the fact the resource base of firms with incremental innovations is sufficient, the local environment is not important for these firms.
2. The role of proximity becomes even more important in the case of firms with radical product and process innovations. As a result of a lack of standard criteria for evaluating technological opportunities and user needs, so-called ‘subjective’ elements, like trust, become important. Subsequently, the majority of suppliers or buyers should be located in the proximity of the innovating firm.

Insert Table 11

The table shows that there are no differences between firms with incremental and radical process innovations with regard to the spatial distribution of suppliers most important for their innovation process. The same is true for the relations of such firms with buyers. As regards firms with product innovations, some differences can be noted. Although the percentages of firms with relations with suppliers located in the southern part of the Netherlands are nearly equal, especially firms with radical product innovations have a high percentage of relations with suppliers outside the Netherlands. A comparison of firms with incremental or radical product innovations and their relations with buyers shows that a relatively high proportion of the buyers of firms with incremental product innovations are located in the proximity of the innovator.

In sum, there are some differences between incremental and radical process or product innovators regarding the spatial distributions of their buyers and suppliers important for innovation, but the overall picture does not lead to a confirmation of Lundvall’s and Maillat’s ideas about the relation between the character of technical change and the interactions in space. The expected importance of proximity for firms with radical innovations in particular is not found.

CONCLUSIONS AND DISCUSSION

In this paper, learning organisations were depicted as problem-solving agents. The obvious negative relation between the number of innovation problems and results of innovation (question 1) was not confirmed. Our interpretation of this result was that learning organisations were able to cope with these problems in such a way that their innovation outcomes were not hampered.

Next, the ways in which firms coped with these innovation problems was investigated (question 2 and 3). Using an empirical application of Håkansson's economic network model, evidence was found that a combination of the use of internal and external knowledge bases improved innovation results. So, the importance of the relational perspective on innovation processes was confirmed empirically. But, the estimations proved to be sensitive to the amount of innovation problems encountered by firms. Higher levels of innovation problems were associated with the utilisation of more, and a more diverse set of, external knowledge bases contributing to the innovation process. These findings stress the fact that the embeddedness or the relational perspective on innovation should not always be taken for granted. The strong emphasis in present day literature on the importance of interorganisational relations for the economic performance is mitigated by our empirical findings. The innovative performance of firms is not always influenced by the extent to which firms are embedded. More particularly, firms with low levels of innovation problems proved to be utilising internal knowledge bases only.

Our findings concerning the importance of proximity in systems of innovations were somewhat puzzling. On the one hand, a large number of the innovative relations with buyers and suppliers most important for the innovation process were found in the proximity of the innovating actor. As a consequence of this result, one can conclude that proximity is indeed of importance. On the other hand, it turned out that the assumptions of Lundvall and Maillat were not confirmed. First, innovative relations with buyers and suppliers located in the southern part of the Netherland were just as knowledge intensive as relations with buyers and suppliers located in other areas. Second, the expected importance of proximity especially for firms with radical product and process innovations was not found.

From these findings one can conclude that proximity is indeed of importance for the innovating firms in our research, but other variables than the one proposed by Lundvall and Maillat influence the spatial distribution of innovative relations in the system of innovation. Research by Oerlemans, Meeus and Boekema (1998: 36-43) has shown that firm characteristics, such as firm size, were better predictors of the spatial distribution of innovative relations, than the extent of knowledge transfer. Smaller firms were more spatially embedded than large firms. Such results indicate that the development stage that a firm is in has greater influence on its composition of spatial relations than the features of its innovation process. Therefore, future research should have a greater focus on the life cycle of the firm and its relation with spatial embeddedness.

Notes

1. The variety argument of Håkansson is a variation on Granovetter's idea of weak ties. In his famous article 'The Strength of Weak Ties' (1973), Granovetter argues that actors receive most new (innovative) information through their weak ties with other networks.

2. The taxonomy consists of four sectors

Pavitt sector	Typical industries
Supplier Dominated	Textiles; Leather goods and footwear; Furniture; Paper and board; Printing
Scale Intensive	Food; Metal products; Glass; Cement; Transport vehicles
Specialised Suppliers	Machinery; Instruments; Opticals
Science Based	Chemicals; Plastics; Electronics

3. Firms were asked to judge these performance improvements on a Likert scale with values ranging from (1) 'very little' to (5) 'very much'. The highest possible score of this compounded variable was 8, the lowest 0.

4. Firms were asked to judge the impact of these knowledge bases on the innovation process on a Likert scale with values ranging from (1) 'never' to (5) 'always'. Regarding the internal knowledge bases, we distinguished functions instead of departments because a large part of our population of firms consisted of SMEs.

5. In this analysis one of the two variables describing latent knowledge deficiencies is used as a moderating variable. The main reason for this is that the variable LKD1 gives us the best indication of the difficulties during the innovation process. In our view, the variation in problems is a better indicator for this level of difficulty than the stages of the innovation process in which they occur.

6. The three factors were found using a varimax rotated principal components analysis. The KMO measure of sampling adequacy was 0.767. Bartlett's Test of Sphericity was 1008.38 (sign. 0.0000). The cumulative percentage of variance explained was 51.5%.

7. The southern part of the Netherlands is a region containing three provinces all located in the south of the Netherlands: Noord Brabant, Zeeland, and Limburg.

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Table 1: Measurements of the variables used for research question 1

Variable	**Descriptions**	**Indicator**
	Dependent variable	
IR	Innovation results	Product and/or process innovations resulted in: • cost price reduction • quality improvement of products or processes • increased production capacity • delivery time improvement • sales increase • profit increase
	Independent variables	
LKD1	Number of innovation problems by nature (latent knowledge deficiency)	• exceeding time planning • product deficiencies • technical production deficiencies • exceeding budgets • bad timing • wrong partners • reaction of competitors • insufficient market introduction efforts
LKD2	Number of innovation problems by stage (latent knowledge deficiency)	• idea formation • economic feasibility • technical feasibility • technical realisation • implementation • introduction and production
MKD	Manifest knowledge deficiencies	1. Shortage of skilled workers (dummy) 2. Lack of technical knowledge (dummy)

Table 2: OLS estimates with innovation results as the dependent variable and latent and manifest knowledge deficiencies as independent variables

Independent variables	Beta
Latent knowledge deficiencies:	
LKD1	0.04
LKD2	0.06
Manifest knowledge deficiencies:	
Shortage of skilled workers	-0.10*
Lack of technical knowledge	-0.11*
R^2	0.03
Adj. R^2	0.02
F value	2.21
Sign. F	0.068

* p < 0.10, ** p < 0.05, *** p < 0.01, **** p < 0.001

Table 3: Measurement of variables used for research questions 2 and 3

Variable	Description	Indicators
		Moderating variable
LKD1	Number of innovation problems	see Table 2
		Dependent variable
IR	Innovation results	see Table 2
		Independent variables
TF	Use of knowledge base of the transformation function	• R&D function • Production function
TA	Use of the knowledge base of the transaction function	• Marketing/sales function • Purchase function
EC1	Use of public knowledge bases	Contributions to the innovation process by (technical) universities and colleges for professional and vocational education
EC2	Use of private knowledge bases	Contributions to the innovation process by intermediaries (Innovation Centres and Chambers of Commerce) and the private knowledge infrastructure (trade organisations, National Centre of Applied Research [TNO], private consultants)
EC3	Use of business knowledge bases	Contributions to the innovation process by important buyers, suppliers, and competitors
TP	Technology policy	Number of technology policy instruments used by a firm

Table 4: Results of factor analysis on the use of external knowledge bases

Factors and items	Factor Coefficients	Labels of knowledge bases
Factor 1 (EC1):		
Technical universities	0.78	
Other universities	0.74	Contributions of the public
Colleges	0.74	knowledge infrastructure
MBO	0.58	
Factor 2 (EC2):		
Trade organisations	0.70	
Regional Innovation Centres	0.66	Contributions of private
Chambers of Commerce	0.66	knowledge infrastructure
National Centre of Applied Research (TNO)	0.59	
Consultants	0.49	
Factor 3 (EC3):		
Important buyers	0.73	Contributions of the
Important suppliers	0.72	Production chain
Competitors	0.66	

Table 5: OLS estimates with innovation results as the dependent variable and the use of internal and external knowledge bases for the innovation process as independent variables: a comparison between different levels of innovation problems

Independent Variables	Problem levels in innovation process			TP (n = 216)
	Low (n=54)	Medium (n = 60)	High (n = 145)	
Internal knowledge bases:				
Transformation (TF)	0.46***	-0.05	0.03	0.26****
Transaction (TA)	0.11	0.32**	0.21***	0.07
External knowledge bases:				
EC1	-0.12	-0.17	0.01	-0.02
EC2	0.16	0.18	0.22***	0.18***
EC3	0.21	0.02	0.37****	0.24****
TP	-0.05	-0.08	0.18**	0.10
R^2	0.22	0.11	0.27	0.19
Adj. R^2	0.20	0.08	0.25	0.17
F value	13.19	5.56	12.84	16.017
Sign. F	0.001	0.022	0.000	0.000

* p < 0.10, ** p < 0.05, *** p < 0.01, **** p < 0.001

Table 6: Spearman rank correlations between the results of innovation and the use of specific internal and external knowledge bases

Level of problems innovation projects		
Low	Medium	High
Items Transformation R&D (0.25*) Production (0.49***)	*Items Transaction* Purchase (0.38**) Marketing (0.17)	*Items Transaction:* Purchase (0.11) Marketing (0.13*) *Items EC2:* Trade organisation (0.13) Innovation Centres (0.16*) Chamber of Commerce (0.01) TNO (0.15*) Consultants (0.22***) *Items EC3:* Important buyers (0.20**) Important suppliers (0.31***) Other firms (0.21**)

* p < 0.10; ** p < 0.05; *** p < 0.01

Table 7: Measurement of variables used for research question 4

Variable	**Description**	**Indicators**
TS	Type of supplier most important for innovation	(1) raw materials; (2) components; (3) machines & tools; (4) consultants
TB	Type of buyer most important for innovation	(1) consumer; (2) retail/wholesale; (3) industrial user
LS LB	Location Supplier Location Buyer	(1) Southern part of the Netherlands; (2) Elsewhere in the Netherlands; (3) Abroad
KT	Knowledge Transfer	(1) never; (2) sometimes; (3) regularly; (4) often; (5) always
TI	Type of innovation	(1) no innovations; (2) process innovation; (3) product innovation
LI	Level of innovation	(1) incremental; (2) radical

Table 8: Spatial distribution of suppliers and buyers most important for the innovation process

Type supplier	Location supplier		
	SN	EN	AB
Raw materials (n = 54)	29.6%	35.2%	35.2%
Components (n = 79)	43.0%	22.8%	34.2%
Machines (n = 125)	27.2%	36.0%	36.8%
Consultants (n = 15)	53.3%	46.7%	0.0%
Total (n = 273)	33.7%	32.6%	33.7%
Type buyer	Location buyer		
	SN	EN	AB
Consumer (n = 13)	38.5%	61.5%	0.0%
Retail/wholesale (n = 104)	26.9%	53.8%	19.2%
Industrial user (n = 160)	48.8%	26.3%	25.0%
Total (n = 277)	40.1%	38.3%	21.7%

SN= Southern part of the Netherlands; EN = Elsewhere Netherlands; AB = Abroad

Table 9: Spatial distribution of suppliers and buyers most important for the innovation process and the extent of knowledge transfer

Knowledge transfer	Location supplier			Total
	SN	EN	AB	
Sometimes	26.1%	25.3%	20.0%	23.8%
Regularly	29.3%	34.5%	38.9%	34.2%
Often	44.6%	40.2%	41.1%	42.0%
Knowledge transfer	Location buyer			Total
	SN	EN	AB	
Sometimes	35.4%	49.5%	38.3%	41.4%
Regularly	37.2%	29.5%	31.7%	33.1%
Often	27.4%	21.0%	20.0%	25.5%

SN = Southern part of the Netherlands, EN = Elsewhere Netherlands, AB = Abroad

Table 10: Spatial distribution of suppliers and buyers most important to the innovation proces: a comparison between types and levels of innovation

Location of suppliers	**Level of innovation**			
	Process innovations (n = 230) (χ^2 = 0.39, sign. = 0.823)		**Product innovation** (n = 214) (χ^2 = 1.76, sign = 0.416)	
	Incr. (n = 187)	**Rad.** (n = 43)	**Incr.** (n = 164)	**Rad**. (n = 50)
SN	33.2%	32.6%	35.4%	34.0%
EN	34.2%	30.2%	29.9%	22.0%
AB	32.6%	37.2%	34.8%	44.0%
Location of buyers	**Process innovation** (n = 226) (χ^2 = 0.13, sign. = 0.939)		**Product innovations** (n = 226) (χ^2 = 2.18, sign. = 0.336)	
	Incr. (n = 178)	**Rad**. (n = 48)	**Incr**. (n = 164)	**Rad**. (n = 62)
SN	38.2%	35.4%	36.0%	25.8%
EN	37.6%	39.6%	40.2%	48.4%
AB	24.2%	25.0%	23.8%	25.8%

SN = Southern part of the Netherlands; EN = Elsewhere in the Netherlands, AB = Abroad. Incr. = incremental innovations; Rad. = Radical innovations